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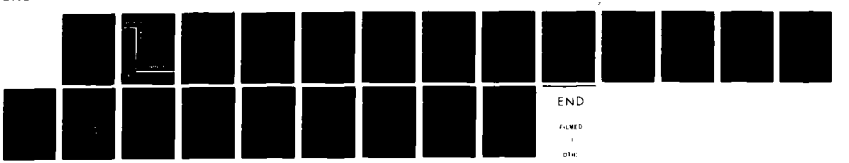

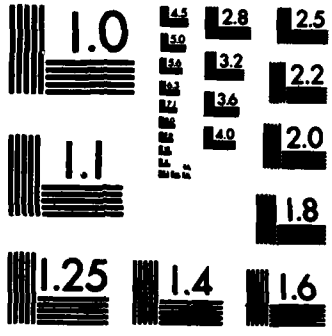

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AIR FORCE HUMAN RESOURCES LABORATORY

COMPUTER BASED MAINTENANCE AIDS SYSTEM: PRELIMINARY DEVELOPMENT AND EVALUATION OF A PROTOTYPE

By

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September 1982

AIR FORCE SYSTEMS COMMAND
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This technical paper describes preliminary work on a project to develop and evaluate a prototype computer based system for storing, retrieving, and presenting technical data for use by maintenance personnel. The work was accomplished under three contracts. Under the first two contracts, the feasibility of developing a computer based system was established and the basic concepts and requirements for the system were developed. Two areas of concern in the development of the system were identified: (a) The need to have the technical data "match" the skills of the technician and (b) the need to "fill the gaps" in the individual's knowledge and skills. The problem of making the technical data match the skills of the technician was addressed with the concept of multiple tracks of information. Under this concept, the technical data are developed at three levels of detail for use by highly experienced and novice personnel. The problem of "filling the gaps" was addressed by the "pool concept." Under this concept, the technicians are provided with "pools" of information which they can call

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up (e.g., instructions on how to set up test equipment). Under the third contract, preliminary work was accomplished on developing the man/machine interface, presentation formats and system design.

AFHRL Technical Paper 82-24 September 1982

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This publication is primarily a working paper.
It documents the work performed.

PREFACE

This technical paper summarizes and briefly describes work accomplished under Project 2362, Computer Based Maintenance Aids for Technicians. The objective of the project is to develop and evaluate a prototype computer based system for the storage, retrieval, and presentation of technical data for use by maintenance personnel to maintain Air Force Systems. The prototype system and the knowledge gained in developing and evaluating it are to be the basis for the development of an automated technical data system for operational Air Force use.

The work described in this technical paper was accomplished under three contracts. The first effort, Human Factors Study of an Automated Technical Order System, was accomplished by Behavioral Technology Consultants, Inc. under contract F33615-77-C-0043. Dr. Thomas W. Frazier was the principal investigator. The second effort was accomplished by Behavioral Technology Consultants, Inc. under conract F33615-78-C-0030. Dr. Thomas W. Frazier was the principal investigator for this effort also. The third effort discussed in this paper was accomplished by Unified Industries, Inc. Mr. Walter Holmes was the principal investigator. The human factors portion of this effort was accomplished under subcontract by BioTechnology, Inc. Mr. G. Richard Hatterick served as the principal investigator for this portion of the study.

COMPUTER BASED MAINTENANCE AIDS SYSTEM: PRELIMINARY DEVELOPMENT AND EVALUATION OF A PROTOTYPE

This technical paper describes preliminary work on a project to develop and evaluate a computer based maintenance aids system. The system will be designed to store, retrieve, and present (on a computer display) data for use by technicians in performing maintenance on Air Force systems. The prototype system and results of the evaluation will provide the basis for the development of a computer based technical data presentation system for operational use. This system will become an integral part of the Automated Technical Order System (ATOS) being developed by the Air Force Logistics Command.

Work toward developing the system has been accomplished under three contracts. This paper briefly summarizes the results of those studies.

BACKGROUND

It has been recognized for many years that conventional Air Force technical orders (TOs) used to support maintenance personnel in the performance of maintenance tasks are often difficult to use, incomplete, poorly organized, and written in terminology that is difficult to understand. Since 1962 the Air Force Human Resources Laboratory (AFHRL) has conducted research programs to develop improved types of technical data for aircraft maintenance. The emphasis has been placed upon developing data which are designed for easy use by maintenance technicians. These research and development efforts have produced a new type of technical data known as job performance aids (JPAs).

JPAs present technical data in a proceduralized step-by-step format which provides detailed illustrations of referenced components. Emphasis is placed on insuring that instructions are complete and presented in clear, easily understood language. In contrast, conventional TOs make only limited use of proceduralized instructions and provide only limited illustrations. Emphasis with conventional TOs is placed on "how it works" more than on "how to fix it."

Available research results indicate that the use of JPAs can result in significant improvements in maintenance performance and that JPAs are well received by maintenance personnel. One problem associated with the use of JPAs is that JPAs require many more pages to cover a system than do TOs. This adds an additional burden to the already over-burdened TO system. It has been estimated that conventional TOs require between 300,000 and 500,000 pages to describe a modern complex weapon system. This, coupled with the additional pages necessary for JPAs, results in a prohibitive amount of paper and an unwieldy system. Increasing system complexity, the consequent necessity for more TO pages, and increasing costs for technical data make it essential that a more economical technical order system be found.

An automated job performance/maintenance aid system which utilizes computer terminals to store and present technical data has the potential for meeting the needs of field technicians at lower costs. A computer based system would permit data to be presented in the step-by-step formats required by JPAs and would offer many additional performance enhancement features not possible with a paper based system. Ready access to any TO on the system would eliminate the lengthy search time now encountered in locating information in TOs. In addition, the system would allow changes and updates to TOs to be done faster and more economically.

Design Criteria

An effective automated job performance/maintenance aid system must meet two main criteria: (1) It must meet all of the technicians' needs for information, and (2) It must easily be used and acceptable to the technician.

The maintenance aids system must provide the following types of information:

1. Procedures for troubleshooting and non-troubleshooting tasks.
2. System information - descriptions, tables of tolerances and capacities, theory of operation, parts information, etc.
3. Diagrams - schematics, wiring, hydraulics, etc.

An information system can contain all required information (and more) and still not be effective if it is not used and accepted by the technician. For a system to be used and accepted it should:

1. Be simple to use and require only limited training to use it.
2. Provide for rapid retrieval of any required information.
3. Require only simple skills to operate (i.e., no typing or computer skills required).
4. Present information in a clear, readable format.
5. Provide information at a level of detail appropriate for the intended user.

Early Studies

Two studies were conducted to develop the basic concepts and structure of the computer based maintenance aids system. These studies were conducted by Behavioral Technology Consultants (contract number F33615-77-C-0043) and Behavioral Technology Corporation (contract number F33615-78-C-0030). Dr. Thomas W. Frazier was the principal investigator for both studies. The

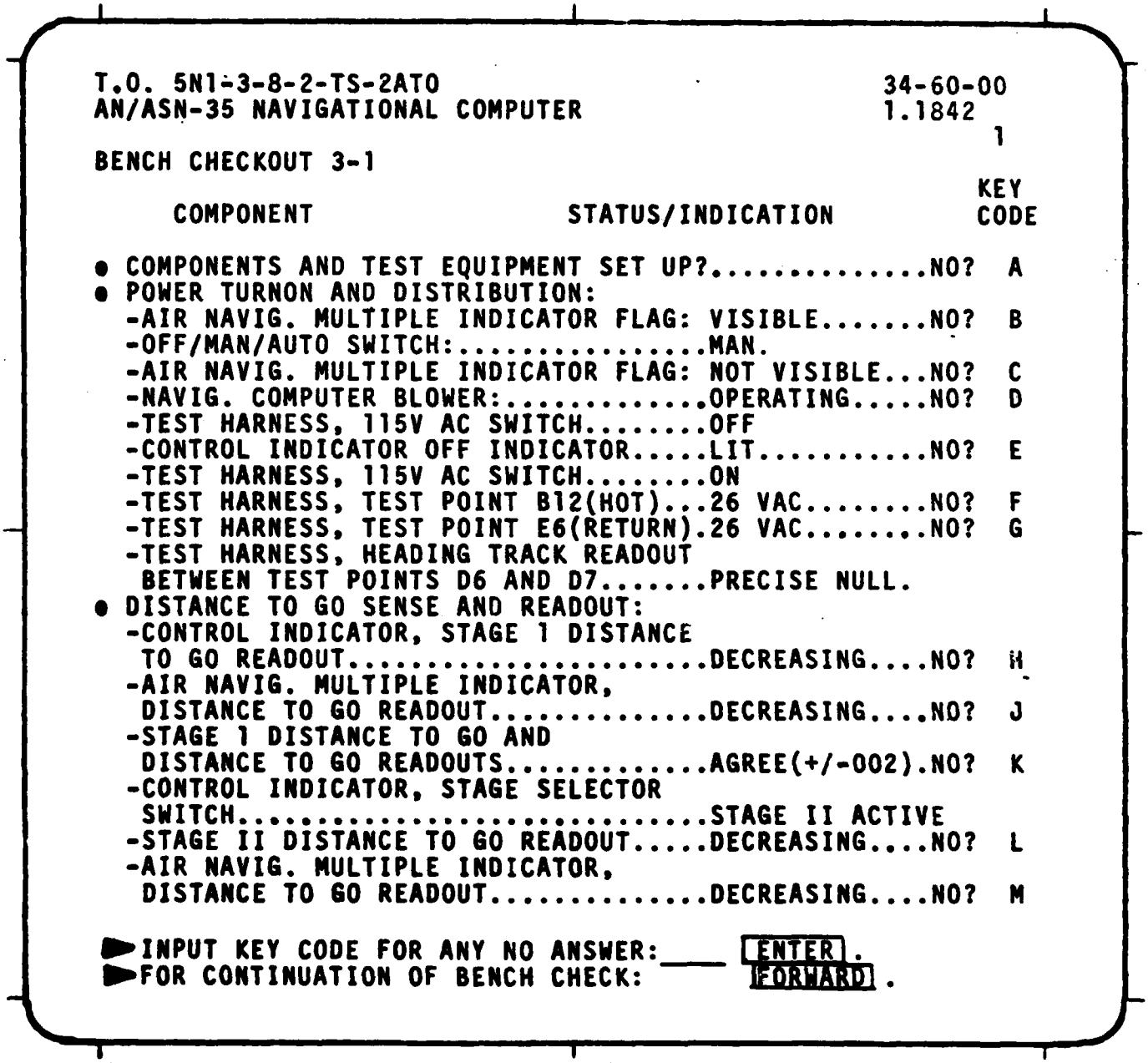
purpose of these studies was to investigate fully the feasibility of developing a computer based job performance aiding system. A major objective was to develop the formats and presentation techniques for the technical data with the maintenance technician in mind. Areas of investigation included the design and management of: Man-machine dialogue for technician-system communications, technical data content in textual form, and supportive graphics.

In the study of technical data content, two areas of concern emerged: (1) matching technical data to general skill levels of maintenance technicians, and (2) filling the gaps in the individuals' repertoire of skills. The first area was addressed by the concept of information "tracks," and the second by information "pools."

Three distinct informational tracks were proposed, each implementing a different level of instructional (aiding) detail and proceduralization of instructions:

Track I - notes about technical aspects of the job, including tolerance information and problems which might be encountered in the course of the job, as well as reminders of some correct procedural aspects of the job and special procedures. This track was intended for use by highly experienced (skill level 7) technical maintenance personnel. An example of the level of detail to be provided in Track I data is presented in Figure 1.

Track II - checklists of tasks to be performed to complete the job presented one task at a time, with access to pools. This



T.O. 5N1-3-8-2-TS-2ATO 34-60-00
AN/ASN-35 NAVIGATIONAL COMPUTER 1.1842
1

BENCH CHECKOUT 3-1

COMPONENT	STATUS/INDICATION		KEY CODE
• COMPONENTS AND TEST EQUIPMENT SET UP?		NO?	A
• POWER TURNON AND DISTRIBUTION:			
-AIR NAVIG. MULTIPLE INDICATOR FLAG: VISIBLE		NO?	B
-OFF/MAN/AUTO SWITCH:	MAN.		
-AIR NAVIG. MULTIPLE INDICATOR FLAG: NOT VISIBLE		NO?	C
-NAVIG. COMPUTER BLOWER:	OPERATING	NO?	D
-TEST HARNESS, 115V AC SWITCH	OFF		
-CONTROL INDICATOR OFF INDICATOR	LIT	NO?	E
-TEST HARNESS, 115V AC SWITCH	ON		
-TEST HARNESS, TEST POINT B12(HOT)...26 VAC		NO?	F
-TEST HARNESS, TEST POINT E6(RETURN).26 VAC		NO?	G
-TEST HARNESS, HEADING TRACK READOUT BETWEEN TEST POINTS D6 AND D7	PRECISE NULL.		
• DISTANCE TO GO SENSE AND READOUT:			
-CONTROL INDICATOR, STAGE 1 DISTANCE TO GO READOUT	DECREASING	NO?	H
-AIR NAVIG. MULTIPLE INDICATOR, DISTANCE TO GO READOUT	DECREASING	NO?	J
-STAGE 1 DISTANCE TO GO AND DISTANCE TO GO READOUTS	AGREE(+/-002)	NO?	K
-CONTROL INDICATOR, STAGE SELECTOR SWITCH	STAGE II ACTIVE		
-STAGE II DISTANCE TO GO READOUT	DECREASING	NO?	L
-AIR NAVIG. MULTIPLE INDICATOR, DISTANCE TO GO READOUT	DECREASING	NO?	M

► INPUT KEY CODE FOR ANY NO ANSWER: ____ [ENTER].
► FOR CONTINUATION OF BENCH CHECK: [FORWARD].

Figure 1. Example Frame from Track I Checkout Data*

*Prepared under contract F33615-79-C-0021

track included only information about what tasks are to be performed (within the track), reference data and tolerances and notices of pool availability for further aid when necessary. This track was intended for primary use by experienced (skill level 5 or 3) maintenance personnel. An example of the level of detail to be provided in Track II data is presented in Figure 2.

Track III - complete proceduralized instructions regarding each defined step of each job task, with all available data, heavy graphic support for parts location and extensive pool availability for informational gap filling. This track was intended for lower skill level (novice) technical maintenance personnel performing this job for the first time. An example of the level of data to be presented in Track III data is presented in Figure 3.

Extensive opportunities for switching between tracks were made available, so that technical maintenance personnel receiving more or less information than was desired could conveniently move from one track to another, as the informational mismatch was discovered.

The concept of pools refers to the strategy for supporting the performance of technicians who are of a given skill level but have gaps in their knowledge regarding specific aspects of the performance of a particular job. It provides a complementary approach to information tailoring to meet a specific individual's information support needs. It is intended to provide helpful support, including embedded training in prerequisite skills that are well established.

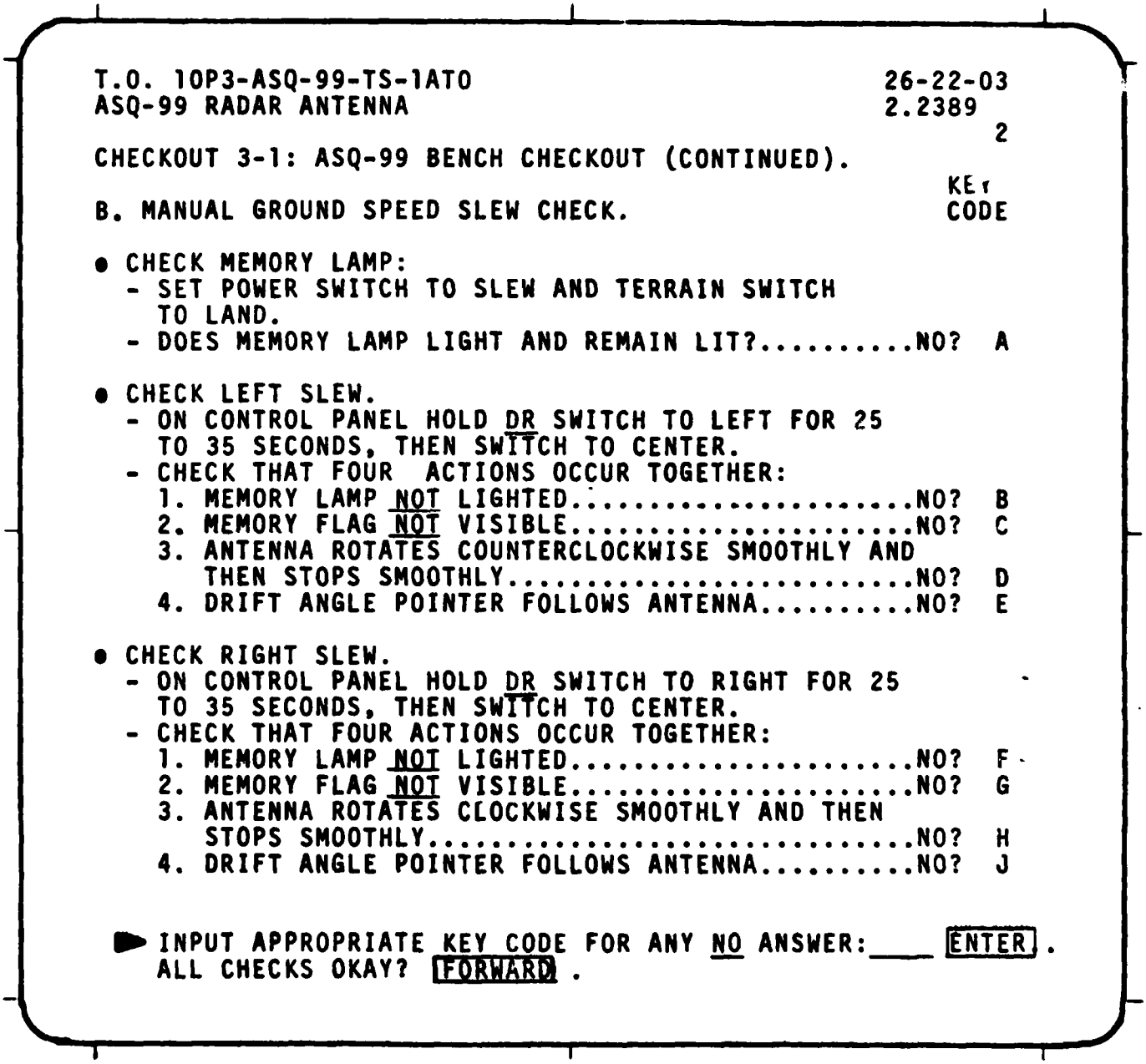


Figure 2. Example Frame from Track II Checkout Procedure*

*Prepared under contract F33615-79-C-0021

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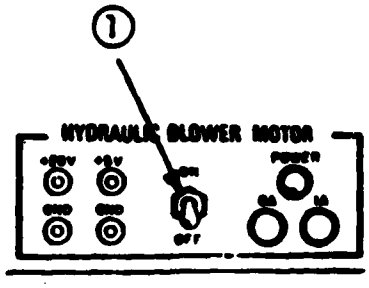
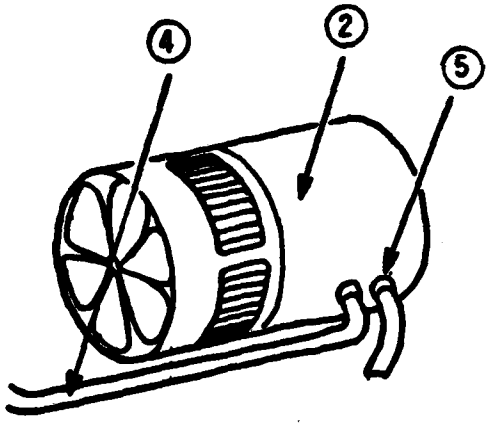
CH495 RADAR, RECEIVER/TRANSMITTER 3.1131
4

LOGIC TREE 10-1: HYDRAULIC BLOWER DOES NOT SPIN WHEN TURNED ON(CONTINUED).

• CAN SURGE BE FELT IN HYDRAULIC HOSE ④ WHEN BLOWER SWITCH IS TURNED ON THEN OFF?
YES.

CHECK MOTOR TO BLOWER SHAFT.
• PLACE MECHANIC'S STETHESCOPE ON OUTLET PORT ⑤ OF MOTOR ②.
• SET MOTOR SWITCH ① TO ON.
• LISTEN FOR A COMBINATION RUMBLING AND WHINING NOISE OF TURNING MOTOR.
DID YOU HEAR MOTOR NOISE?





► INPUT EITHER YES OR NO :___ ENTER .

Figure 3. Example Frame from Track III Troubleshooting Procedure*

*Prepared under contract F33615-79-C-0021

Examples of types of pool information would be theory of operation of equipment, use of special tools, tolerances, methods and procedures, technical information, lists of suitable substitutes for test equipment, and use of test equipment.

The formats proposed for presenting technical data in the three tracks rely heavily on graphics materials. This presents a problem in the development of an automated technical data system since graphics materials require large amounts of storage space and the storage capacity of the system will be limited. However, graphics are essential elements of the data presentation formats. Significant reductions in the number of graphics is not considered to be a viable alternative. Thus, ways must be found to reduce the storage required for each graphic.

There are a number of approaches which may be taken to reduce graphics storage requirements. Most involve techniques for representing the graphics material in the computer itself. These approaches primarily involve computer hardware and software technology. Detailed consideration of them was beyond the scope of the current effort.

Another approach to reducing storage requirements is to reduce the complexity of the graphics themselves. This is primarily a human factors problem and was briefly addressed in this study. The approach taken was to reduce the complexity of graphics by elimination of irrelevant cue information. Thus, instead of presenting an illustration which represents all of the features of the subject equipment in detail, only those features which are necessary to permit location of the pertinent part of the equipment are shown. An example of this approach is shown in Figure 4. Illustration A

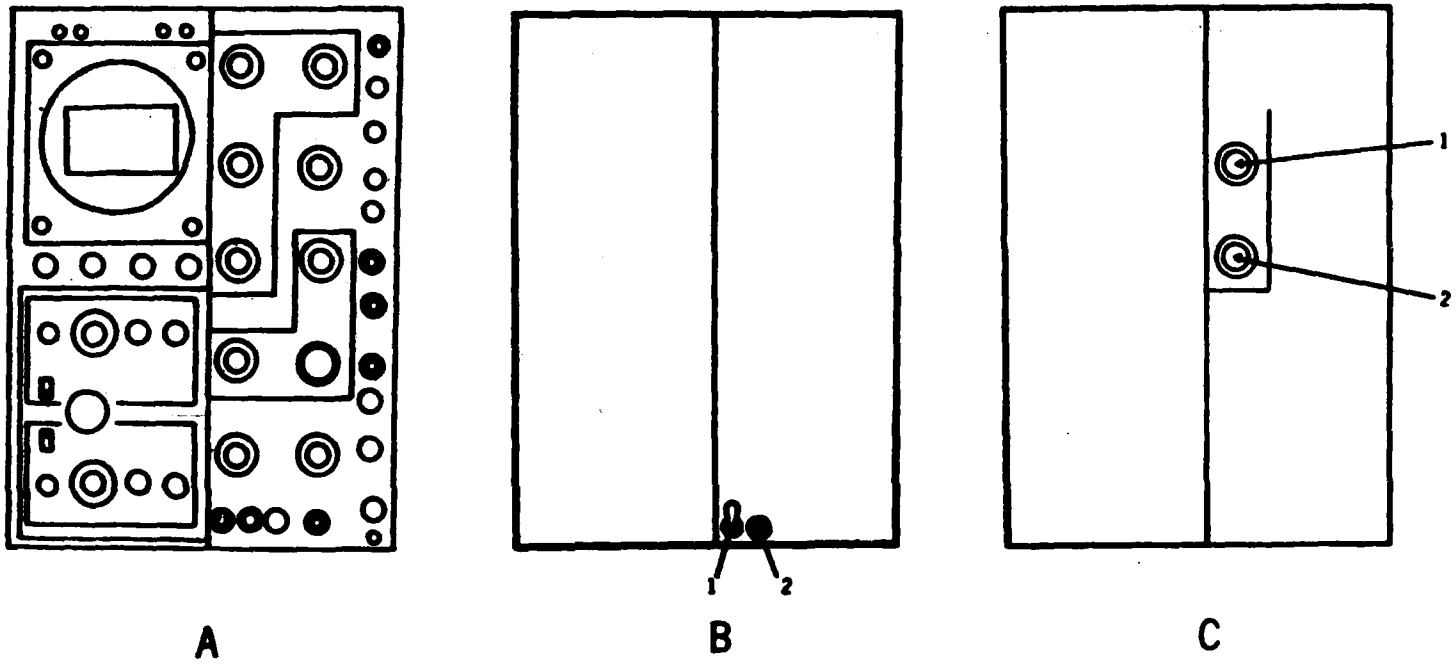


Figure 4. Example of Graphics Simplification Concept*

*Prepared under Contract F33615-78-C-0030

represents a typical line drawing which might appear in a conventional technical order. Illustrations B and C are locator illustrations which present only the cues necessary to locate the pertinent parts. A preliminary evaluation indicates that this approach to reducing the complexity of graphics and thereby reducing strorage requirements is feasible. However, additional work is required to evaluate the effects of reducing irrelevant detail and to establish ground rules for developing graphics with minimal complexity.

Third Contract

The third contract under this project was awarded for the purpose of expanding and refining the concepts developed in the Frazier studies and designing, developing, and evaluating a prototype system. The contract (F33615-79-C-0021) was awarded to Unified Industries, Inc. BioTechnology, Inc. served as a subcontractor for the human factors portion of the study. Mr. Walt Holmes was the principal investigator for Unified Industries, Inc. Mr. G. Richard Hatterick was the principal investigator for BioTechnology, Inc.

Work was initiated on the contract in September 1978 and continued until March 1981 when it was terminated at the convenience of the Government. Contract termination became necessary when a change in requirements for the system was received from the project sponsor, the Air Force Logistics Command. The change added the requirement that the system be suitable for deployment in support of world wide wartime operations. The system under development was designed for use at fixed site locations and was not suitable for deployment. It was determined that it would not be cost effective to modify the system to make it deployable. Thus, the contract was terminated.

Work was performed on several tasks in preparation for the development of the prototype system. Major areas of work included:

1. Identification of technicians' information requirements.
2. Development of the man/machine interface.
3. Identification of hardware requirements.
4. Identification of software requirements, including the design of a file structure.
5. Development of data presentation formats.

The majority of the work accomplished on the contract was in the areas of the man/machine interface and the development of data presentation formats. The emphasis was placed on developing procedures which would allow the technician to rapidly locate and retrieve any desired information with minimum effort. A critical requirement was that the technician not need extensive knowledge of computer system or special skills, such as typing, to use the system. The primary elements of the man/machine interface are a special function keyboard and associated software. The layout of the function keyboard is shown in Figure 5. Using the function keyboard it is possible for the technician to accomplish the following operations with one or two key presses:

Display the next frame in sequence

Return to the previous frame

Display a list of available optional (pool) information

Return (to a procedural frame) from a pool item

Store or recall a frame for later recall

Zoom to make graphics larger or smaller

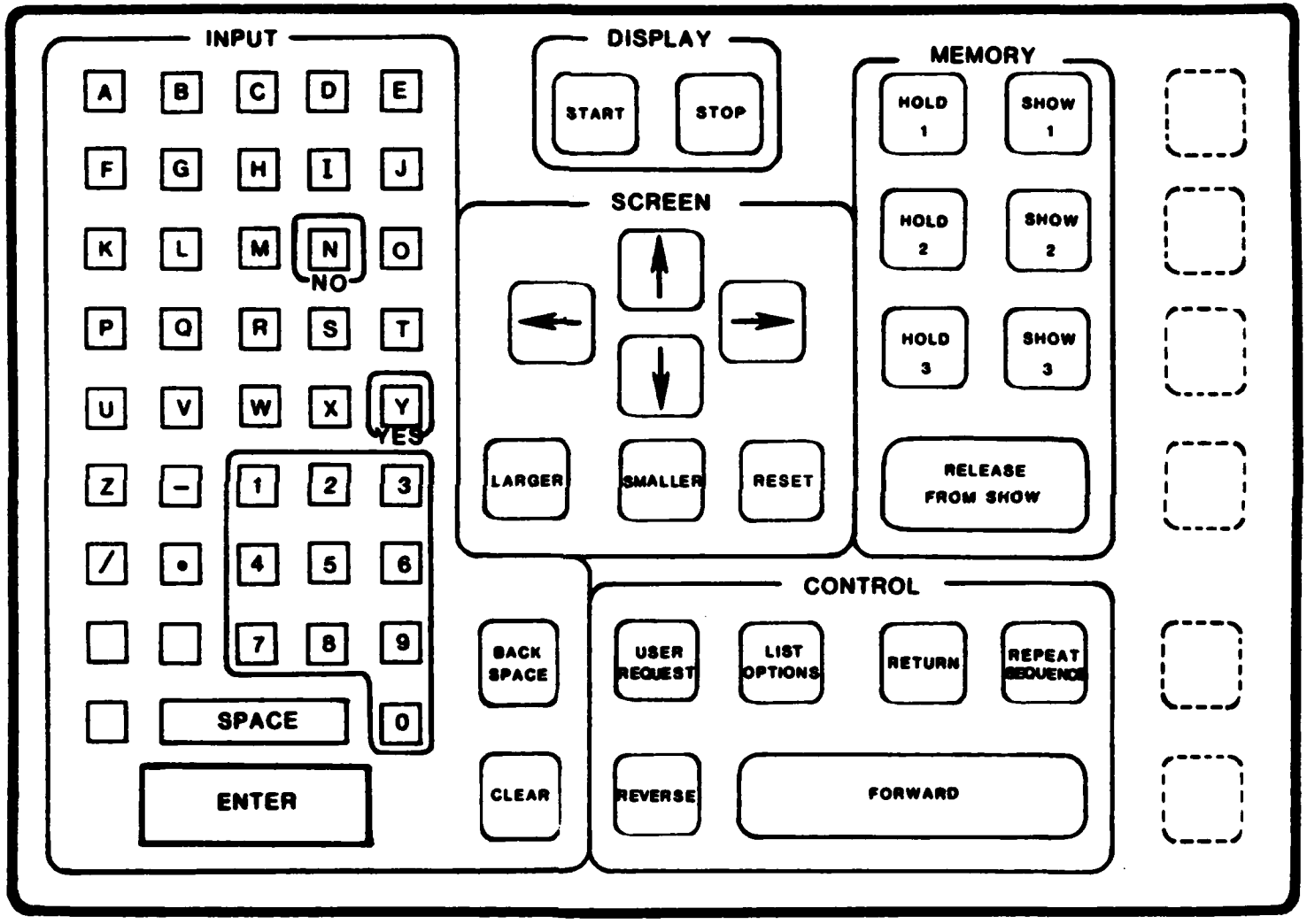


Figure 5. Proposed Layout for Controls on Function Keyboard*

*Developed under contract F33615-79-C-0021.

Using the alphanumeric keys, the technician can retrieve a specific frame or item of information provided that he/she knows one of the following:

Frame Number

Task Number

Fault Code

MIDAS Code

Part Number

Reference Designation

Data presentation formats were developed for Tracks II and III. These formats present step-by-step instructions supported by illustrations in a manner similar to the job guide format. The primary difference between the Tracks I, II and III formats is the level of detail provided. Examples of these formats are presented in Figures 1, 2, and 3. It should be noted that the formats presented are drafts.

Summary

The three studies described in this paper have developed the basic concepts and requirements for an effective computer based maintenance aiding system. Requirements developed emphasize the need to make the system easy to use and the importance of providing quick access to all required information at an appropriate level of detail. Key concepts developed or adapted include:

1. The three-track system which provides instructions at three levels of detail. Technicians select instructions at a level of detail appropriate to their level of experience and training.

2. The pool concept which provides for ready access to a variety of support information.

3. A special function keyboard which provides for easy manipulation of the data base and recall of information with one or two key presses or entry of a short code.

The next step in the program will be to apply these concepts to the development of a deployable computer based maintenance aiding system.